

# Planning and Optimization

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## Exercise Sheet 4 Due: October 24, 2022

**Important:** for submission, consult the rules at the end of the exercise. Non-adherence to these rules might lead to a penalty in the form of a deduction of marks or, in the worst case, that your submission will not be corrected at all.

### Exercise 4.1 (3+1)

Consider the planning task  $\Pi = \langle V, I, O, \gamma \rangle$  with

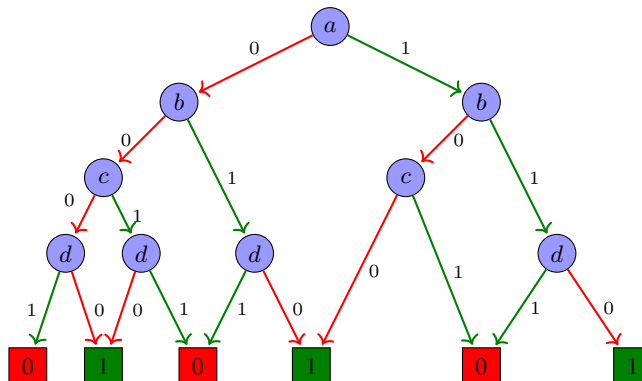
$$\begin{aligned} V &= \{a, b, c\} \\ I &= \{a \mapsto \mathbf{T}, b \mapsto \mathbf{F}, c \mapsto \mathbf{F}\} \\ O &= \{o_1, o_2\} \text{ with} \\ pre(o_1) &= a \\ eff(o_1) &= b \wedge (b \triangleright c) \\ pre(o_2) &= \neg b \\ eff(o_2) &= a \triangleright c \\ \gamma &= c \end{aligned}$$

- Provide all clauses of the propositional formula that is used to test if  $\Pi$  has a plan with horizon  $T = 1$  in the sequential encoding. Annotate each clause with its name as given in the lecture (e.g., initial state clause, operator selection clause, positive frame clause, ...).
- Provide the result that is returned by a SAT solver invoked with the propositional formula from part a). Explain how to interpret the result.

### Exercise 4.2 (2+1 marks)

For both parts, you do not need to show intermediate results, but partial marks may be awarded for wrong results with correct intermediate steps.

- Consider the following ordered BDD:



Provide the equivalent reduced ordered BDD.

- (b) Provide a reduced ordered BDD for the formula

$$\varphi = (a \vee b) \rightarrow (d \vee ((c \vee d) \rightarrow (\neg a \wedge b)))$$

with order  $a \prec b \prec c \prec d$ .

**Exercise 4.3** (2+1 marks)

- (a) Provide a family of unit-cost planning tasks  $\Pi_n$  for  $n \in \mathbb{N}$  where
- (i)  $\Pi_n$  has an optimal plan length of  $n$ ,
  - (ii) (explicit-state) breadth-first search expands an exponential number of states, and
  - (iii) the number of nodes in the reduced ordered BDD  $reached_i$  that is created by breadth-first with progression and BDDs is linear in  $n$ .

Justify why your answer is correct, e.g., by providing the BDD  $reached_i$  for  $1 \leq i \leq n$ .

*Hint: A family of planning tasks that scales with a natural number  $n$  is often defined via a set of variables that depends on  $n$  (e.g.,  $V = \{v_1, \dots, v_n\}$  or  $V = \{v_1, \dots, v_n, v'_1, \dots, v'_n\}$  etc.) and a set of operators that depends on  $n$  (e.g.  $O = \{o_1, \dots, o_n\}$ ).*

- (b) Provide a solvable planning task  $\Pi$  where the parallel SAT encoding is equivalent to the sequential SAT encoding.

**Submission rules:**

- Exercise sheets must be submitted in groups of three students. Please submit a single copy of the exercises per group (only one member of the group does the submission).
- Create a single PDF file (ending .pdf) for all non-programming exercises. Use a file name that does not contain any spaces or special characters other than the underscore “\_”. If you want to submit handwritten solutions, include their scans in the single PDF. Make sure it is in a reasonable resolution so that it is readable, but ensure at the same time that the PDF size is not astronomically large. Put the names of all group members on top of the first page. Either use page numbers on all pages or put your names on each page. Make sure your PDF has size A4 (fits the page size if printed on A4).
- For programming exercises, only create those code textfiles required by the exercise. Put your names in a comment on top of each file. Make sure your code compiles and test it. Code that does not compile or which we cannot successfully execute will not be graded.
- For the submission: if the exercise sheet does not include programming exercises, simply upload the single PDF. If the exercise sheet includes programming exercises, upload a ZIP file (ending .zip, .tar.gz or .tgz; *not* .rar or anything else) containing the single PDF and the code textfile(s) and nothing else. Do not use directories within the ZIP, i.e., zip the files directly. After creating your zip file and before submitting it, open the file and verify that it complies with these requirements.
- Do not upload several versions to ADAM, i.e., if you need to resubmit, use the same file name again so that the previous submission is overwritten.